Quantum theory of Paramagnetism

According to classical theory the atoms of the paramagnetic gas are assumed to be small permanent magnets due to circulating electrons . In the absence of the external magnetic field , the magnetic axes of the atoms are uniformly distributed in all directions .

When the magnetic field applied the atoms will tend to orient themselves with their magnetic axes in the direction of the field .

In quantum theory, the permanent magnetic moment of an atom or ion is not freely rotating but with respect to applied field it is restricted to a finite set of orientations .

If N be the number of atoms per unit volume of the medium and J be the total angular momentum quantum number of each atom , the possible components of the magnetic moment , The magnetic moment ,

$$M_J\, g\, \mu_B \qquad (1)$$

Where M_J = $J , (J-1) , \ldots - (J-1) , -J$

= Magnetic quantum number associated with J .

∴ Potential Energy of a magnetic dipole having component $M_J\, g\, \mu_B$ along H ,

$$= - M_J\, g\, \mu_B\, H \qquad (2)$$

Thus from statistical mechanics

The total magnetic moment per unit volume or the magnetisation along the field direction can be written as

$$M = N \sum_{-J}^{+J} M_J \, g \, \mu_B \, e^{M_J \, g \, \mu B}/KT \; / \; \sum_{-J}^{+J} e^{M_J \, g \, \mu B}/KT \qquad (3)$$

Where g = Lande's spiliting factor

= 1+ J (J+1) + S(S+1) - L(L+1) / 2(J(J+1)

μ_B = Bohr magneton

L = Total orbital angular momentum of each atom

S = Total spin angular momentum of each atom